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Session II. Case Study

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Integrated Data Analysis of July 7, 1990 Microburst
Dave Hinton, NASA Langley

ANALYSIS OF JULY 7, 1990 MICROBURST ENCOUNTER AT ORLANDO, FLORIDA

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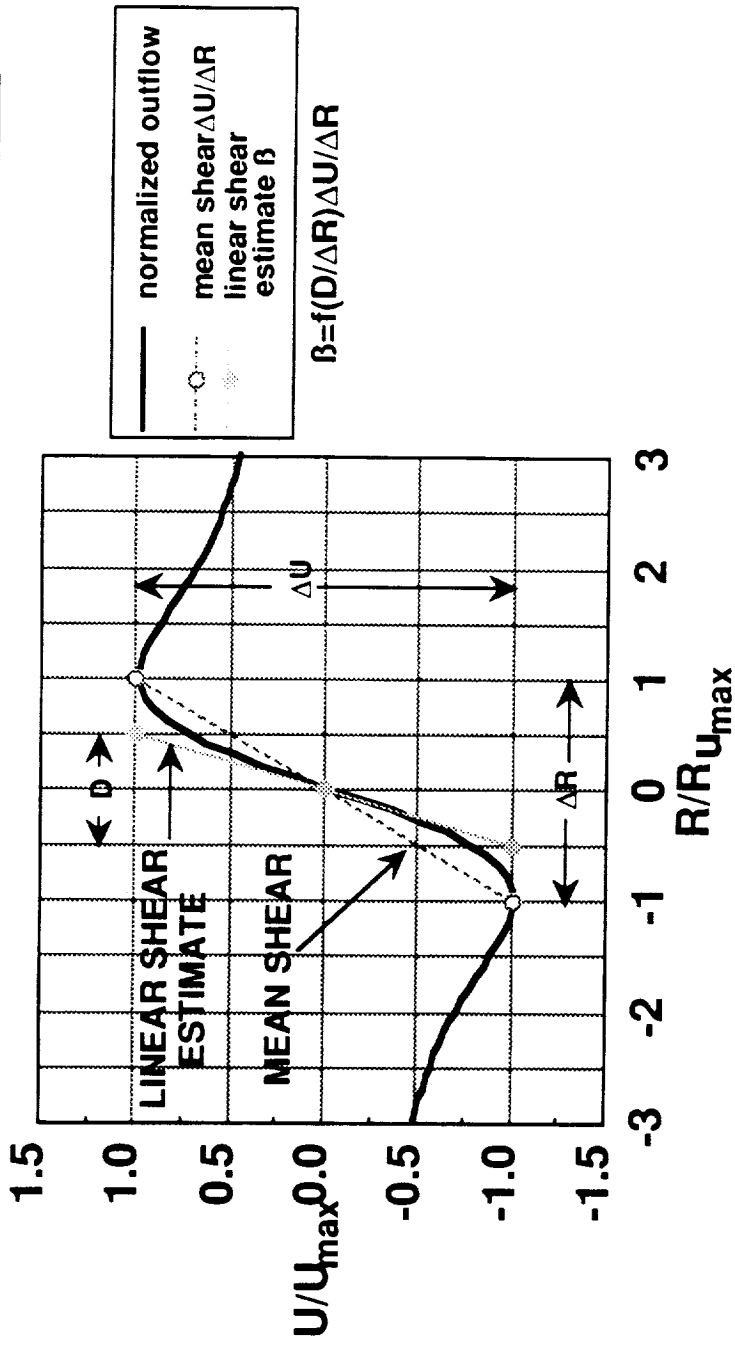
**THIRD COMBINED MANUFACTURERS' AND TECHNOLOGISTS'
AIRBORNE WINDSHEAR REVIEW MEETING
Hampton, VA**

Oct.16 - 18 1990

SUMMER 1990 TDWR FLIGHT EXPERIMENT

- INITIAL EFFORT IN INTEGRATION OF GROUND-BASED WINDSHEAR INFORMATION ON THE FLIGHT DECK
- EVALUATE NASA ALGORITHM FOR ESTIMATION OF MICROBURST F-FACTOR FROM TDWR DATA
- UTILIZE EXISTING RESOURCES AT ORLANDO
 - MIT LINCOLN LAB TDWR
 - UNIVERSITY OF NORTH DAKOTA CESSNA CITATION
 - TURBULENCE PREDICTION SYSTEMS INFRARED WINDSHEAR SYSTEM
- CORRELATE TDWR, AIRCRAFT IN SITU, AND INFRARED WINDSHEAR DATA

LEAST SQUARE ESTIMATE OF LINEAR SHEAR



$$\beta = 4.1925 \frac{\Delta U}{\Delta R} \left[\left(\frac{\Delta R}{D} \right)^2 - \left(\frac{\Delta R}{D} \right)^3 \frac{\sqrt{\pi}}{2.2424} \operatorname{erf} \left(1.1212 \frac{D}{\Delta R} \right) \right]$$

$$F = \beta \left[\frac{V}{g} + \frac{2h}{V} \right]$$

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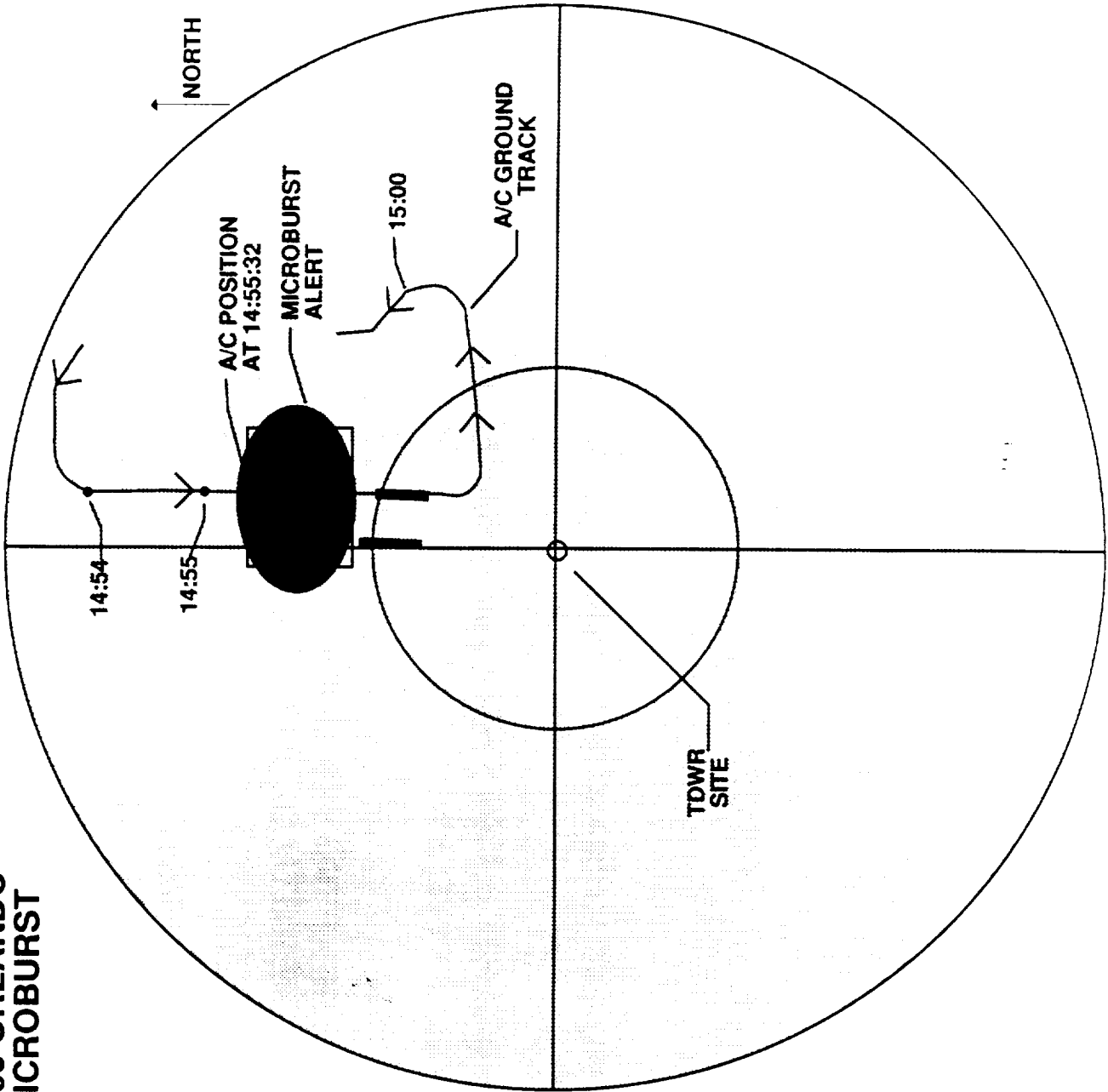
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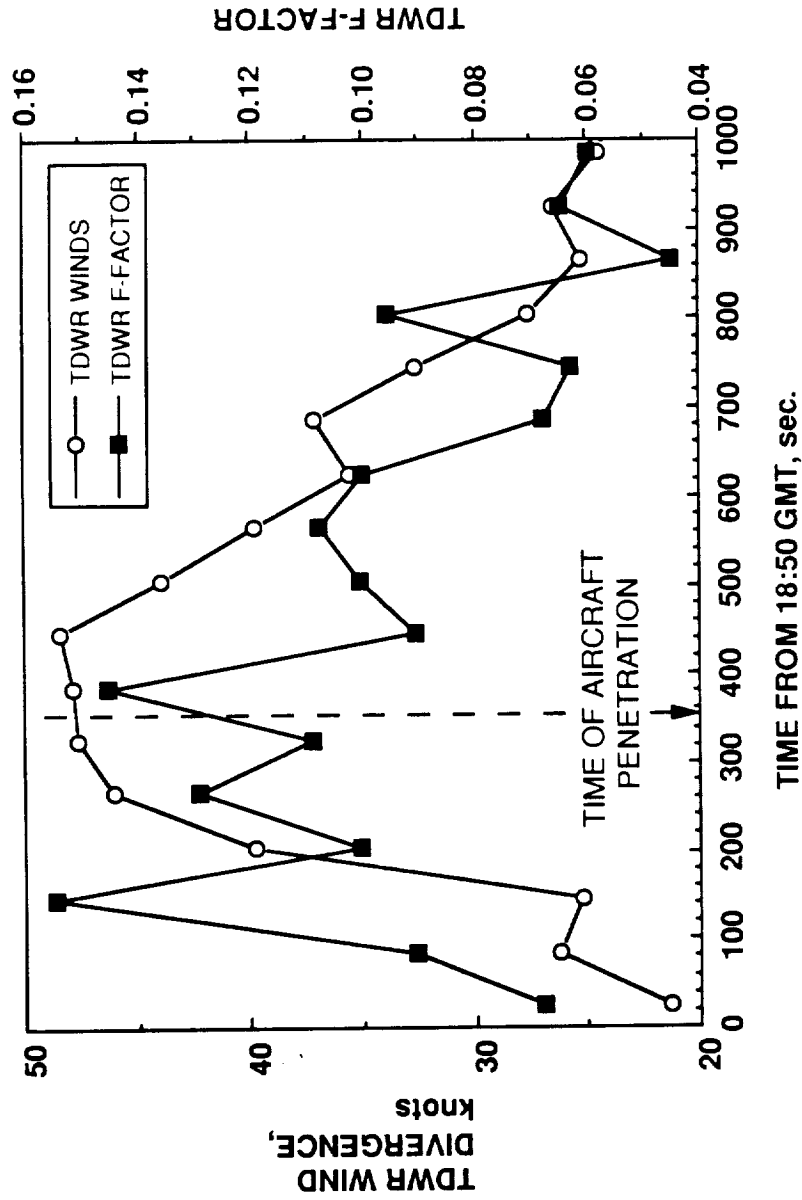
EVENT SYNOPSIS

- **AT ABOUT 18:49 GMT, TDWR DETECTED A 60 DBZ ECHO AND 5 M/S DIVERGENCE ON APPROACH PATH TO RUNWAY 17L**
- **CITATION WAS AIRBORNE AND MANEUVERED FOR MICROBURST PENETRATION**
- **MICROBURST STRENGTH INCREASED RAPIDLY TO 25 M/S DIVERGENCE**
- **CITATION ROLLED OUT ON FINAL APPROACH 70 SECONDS BEFORE RAINSHAFT ENTRY**
- **CITATION PENETRATED CORE OF MICROBURST AT 18:55 GMT NEAR PEAK STRENGTH OF MICROBURST, ON LOCALIZER AND GLIDESLOPE**
- **CORRELATION POSSIBLE BETWEEN TDWR, INFRARED, AND AIRCRAFT IN SITU MEASUREMENTS OF THE EVENT**

7/7/90 ORLANDO MICROBURST

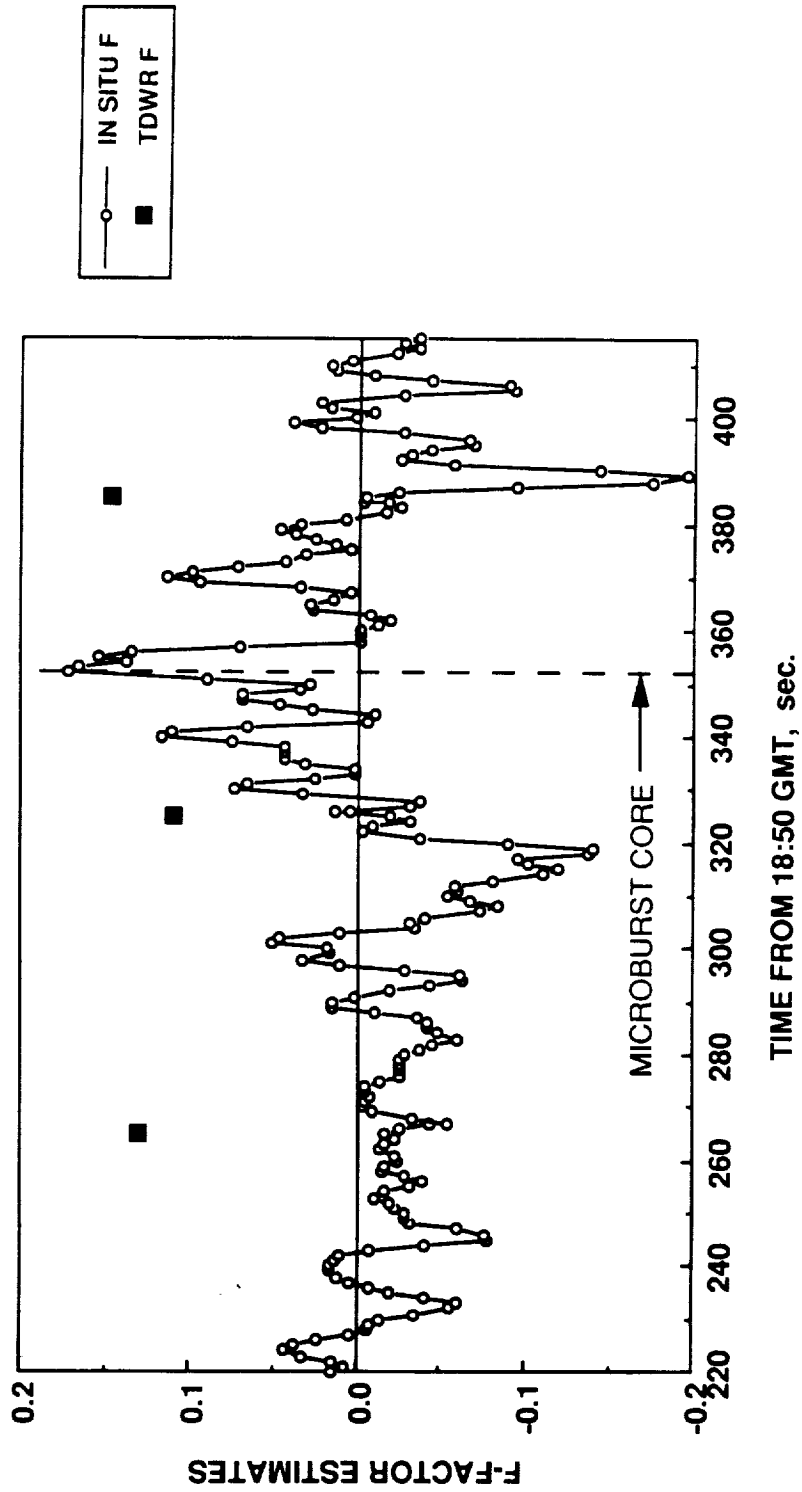


TDWR DATA ANALYSIS



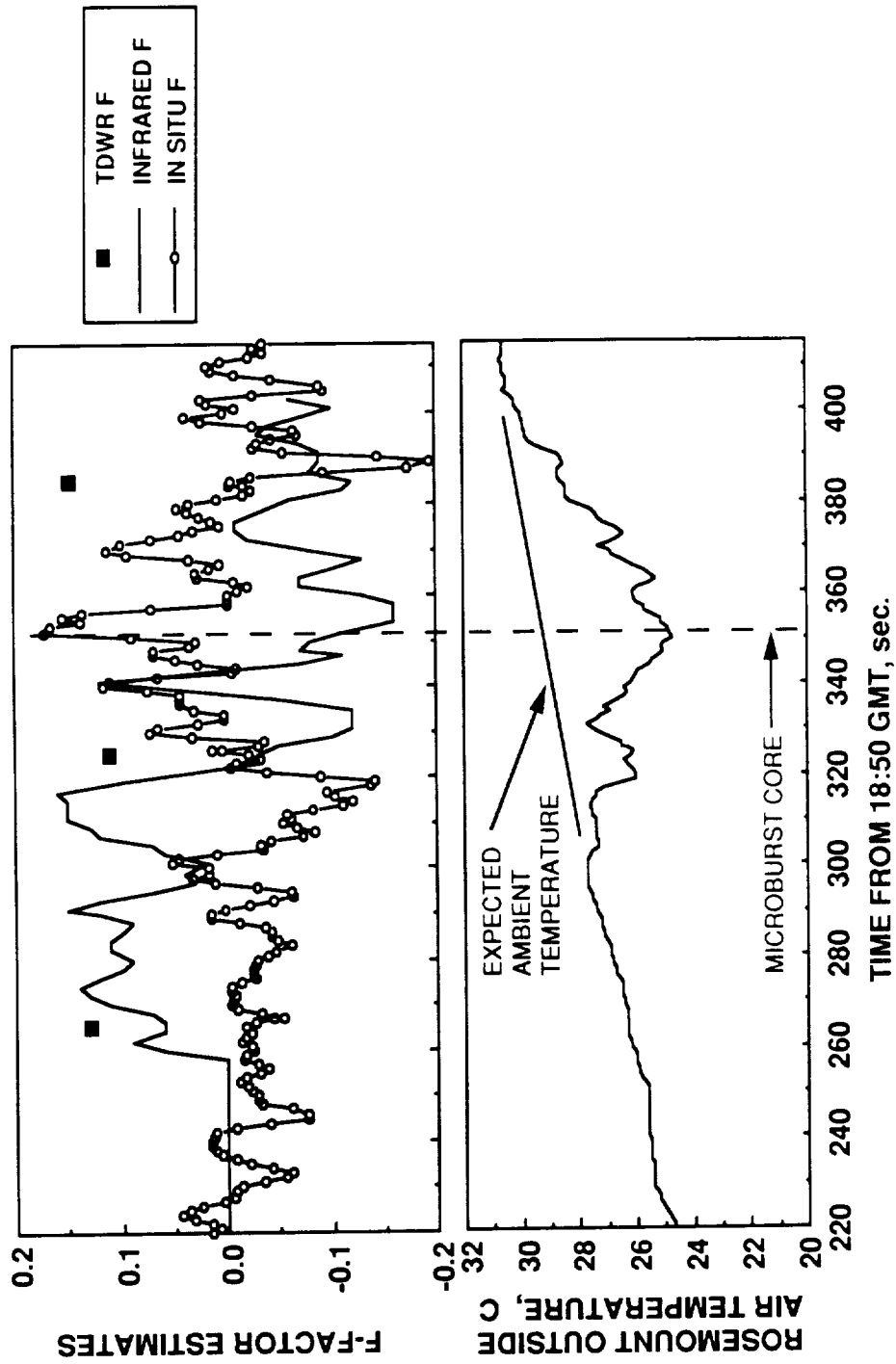
- PEAK DIVERGENCE WAS NEARLY 50 KNOTS (25 M/S)
- PEAK F-FACTOR ESTIMATE WAS 0.15
- F-FACTOR REMAINED ABOVE 0.10 FOR 5 MINUTES

CITATION AIRCRAFT IN SITU DATA ANALYSIS



- F-FACTOR CALCULATED FROM AIRCRAFT RECORDING OF WIND SPEED AND DIRECTION, AIRCRAFT TRACK, AND VERTICAL WIND
- PEAK IN SITU F-FACTOR WAS 0.17, RANGED FROM 0.13 TO 0.16 FOR 4 MORE SECONDS

INFRARED DATA ANALYSIS



- MICROBURST PRODUCED AN IN SITU TEMPERATURE DROP OF ABOUT 4°C
- PEAK INFRARED F-FACTOR WAS 0.16
- INFRARED PROVIDED LEAD TIME OF ABOUT 40 SECONDS

SUMMARY OF JULY 7 EVENT

- **SINGLE EVENT SAMPLED BY TDWR, INFRARED, AND AIRCRAFT
IN SITU**
- **EXCELLENT CORRELATION OF THE THREE F-FACTOR ESTIMATES**
- **POSSIBLY THE FIRST AIRBORNE FORWARD-LOOK MEASUREMENT
OF MICROBURST WINDSHEAR HAZARD VALIDATED BY AIRCRAFT
IN SITU DATA**
- **ANALYSIS OF OTHER EVENTS REQUIRED TO VALIDATE/REFINE
TDWR F-FACTOR ALGORITHM**

Integrated Data Analysis of July 7, 1990 Microburst Questions and Answers

Q: FRED REMER (University of North Dakota) - How would the July 7, 1990 microburst in Orlando have affected a transport category aircraft on a stabilized approach?

A: DAVE HINTON (NASA Langley) - That microburst would have generated, or should have generated a valid alert had any transport aircraft flown through it with a reactive system. The strength of the microburst (with an F-factor of about 0.15 or 0.17, depending on which measurement you take) indicates that an aircraft could have easily recovered from it had the pilot initiated a missed approach. Had the pilot attempted to continue through to landing it would have been somewhat dangerous.

Q: UNKNOWN - You said that it would have generated a light or something from a reactive system. What reactive system are you talking about?

A: DAVE HINTON (NASA Langley) - I said, had a transport category aircraft penetrated that microburst and had such an aircraft been equipped with a reactive system it should have generated a valid alert. This aircraft did not have a reactive system on board.

UNKNOWN - They're not all the same.

DAVE HINTON (NASA Langley) - I realize that; but if they are functioning properly they should have generated an alert. The event was strong enough that the threshold agreed to by the industry was exceeded for some 5 or 6 seconds. There should have been an alert had any system gone through there.

UNKNOWN - I didn't know there was a threshold agreed to by the industry.

DAVE HINTON (NASA Langley) - TSOC117.

UNKNOWN - There are reactive systems out there that were put together long before the TSO came out.

DAVE HINTON (NASA Langley) - I realize that. The "national speed limit" was an F-factor of 0.15 some years ago. I believe most systems in the field, even the older ones are threshold at approximately 0.12 to 0.13, in that ball park. This exceeded that threshold.

ROLAND BOWLES (NASA Langley) - To my knowledge there has never been a case where a reactive system has been tested in a situation where an alert was given and there was independent measurement to confirm the validity of that alert. Now, I'm going to probably start an argument here. There's some people that will probably argue that. The key point is where an alert occurred with a reactive system for which there was independent confirmation; a different data measurement. Now we've had a lot of crews say, "yea, that was about right." But as many of the responses that you get on that side of it, you've got a lot of crews saying, "no way can I accept the validity of that alert." One of the things that we want to do at Denver is to test that hypothesis. There are some subtleties involved here. I'm sure the manufacturers are putting good systems out there, but I know of no program where an alert has been given by purposely testing it in an environment for which there's been independent measurement. In the Orlando case, we had an exceedance of 0.1 for 5 or 6 seconds. It is perfectly believable that the gust rejection filtering in a system could knock that amplitude down and stretch it out in such a way that we may not have gotten an

exceedance of 0.1. Maybe the Honeywell people can comment on that. It depends on whose system it is.

Q: PETER ECCLES (MITRE Corp.) - Aircraft configuration (engine out, load distribution, even pilot experience) would affect aircraft survivability. Given a smart computer which keeps account of aircraft configuration, a combination of F-factor with configuration would give a better idea of a probability of survival. Would you agree?

A: DAVE HINTON (NASA Langley) - I would say from a technical viewpoint, yes, that obviously keeping track of these parameters would give a better idea. I'm not sure that from an operational point of view it's realizable or even desirable. One point of reference is that TSOC117 there is only one threshold given for all aircraft and we know that various aircraft, given all engines, have different recovery performance characteristics.

PETER ECCLES (MITRE Corp.) - We're not particularly stuck with that TSO, I mean there could be other TSOs.

DAVE HINTON (NASA Langley) - I assume that's subject to modification.

Q: BOB ROLL (Lockheed Missiles & Space Co.) - Is the 4 to 6° C temperature drop unique to the microburst type situation or does that occur in every day situations, even in clear weather? Secondly, is there always a temperature drop when a wind shear hazard (not necessarily a microburst) occurs?

A: DAVE HINTON (NASA Langley) - To answer the first part about the temperature drop occurring, it's not unique to microbursts, we also see a temperature drops in gust fronts. Some early infrared detection work was dealing specifically with gust front detection. As far as those temperature changes occurring in other conditions, i.e., sea breeze fronts, temperature inversions, that's still an open question. The current research being conducted, that being the program that Pat Adamson is in with American Airlines on the MD80s and some of the research we will be conducting on our 737, is designed to answer that question. The answer to the second part about are we seeing a temperature drop when a wind shear hazard exists, I suppose I have to ask, how do you define a wind shear hazard? That is, are we only talking about microbursts, are we also trying to determine or detect other types of wind shears. If we look only at microbursts there is a very strong correlation, even a scaling factor between the temperature drop and the strength of the event. If you start looking at other events, sea breeze fronts, convective turbulence, we don't expect to see that temperature correlation. It's not clear that we need to detect those anyway. That's a question industry will have to answer.

MARILYN WILSON (MIT Lincoln Laboratory) - I just want to qualify that a little bit. Some microbursts are not associated with temperature drops at the surface. It depends on where in altitude you look. Aloft there may be a temperature drop, and a strong correlation as you say. But near the surface some microbursts are actually associated with temperature increases.

DAVE HINTON (NASA Langley) - We've seen that. Fred Proctor's model has been able to recreate those situations. It's not clear how often those conditions exist and how strong a microburst tends to be when you get that type of a temperature inversion in stable air. That is another question that has to be answered.

Q: WAYNE SAND (NCAR) - With 62 events penetrated, can we expect a detailed functional analysis of a look-ahead system? If so, when? And, do you always see a temperature deficit in the microburst?

A: DAVE HINTON (NASA Langley) - I would say that as far as the 62 events are concerned the primary emphasis of that study is on correlation of terminal Doppler weather radar based F-factor measurements or estimations with the insitu measurements of the airplane as it goes through. Another objective is the correlation of the infrared F. We plan to correlate that wherever it makes sense to do so. What I mean by that is, there is some penetrations where the aircraft is not stabilized far enough away from the event to give the infrared system a chance to look at it, simply because of the nature of the way the airplane was flown in those events. When will that analysis be completed? It's always dangerous to say when an analysis is going to be completed, as you know. This study is being conducted under contract by Lincoln Labs. The contract was signed very shortly before the data collection started. So, they were only able to recently hire their data processing person. As soon as they automate that data processing we expect to process all of the events as quickly as we can. The final report is due, roughly in the early winter, February, somewhere in that ball park.

Q: JOHN HANSMAN (MIT) - You said that you only have a limited number of cases where you had enough infrared line up on the thing to make a measurement. Is that an inherent limitation on infrared in the future?

A: DAVE HINTON (NASA Langley) - I think we're talking about an inherent limitation of any forward look system. You have to remember these systems are designed to protect transport category aircraft flying instrument approaches, or perhaps visual approaches. But this research aircraft is occasionally making radical maneuvers in order to catch a microburst before it dissipates.

Q: JOHN HANSMAN (MIT) - Does that imply that procedurally, in potential microburst cases with look ahead systems you're going to have to stabilize on the approach sufficiently far ahead of the threat region, and is that any further out than the outer marker?

A: DAVE HINTON (NASA Langley) - No, I don't see that as further out than the outer marker.

A: DAVE HINTON (NASA Langley) - The third part of the question is, "do we always see the temperature drop?" Again I have to go back to the fact that we haven't seen the data yet. We haven't had a chance to look at the data from that experiment. I see that Pat would like to make a comment though.

PAT ADAMSON (Turbulence Prediction Systems) - We haven't actually analyzed the data, but looking at about 20 encounters on the UND aircraft, through the month of July or so, all of the downdrafts that we saw were associated with anywhere from about 3 to 7 degree temperature drops. Now those are all wet microbursts. We haven't reduced the Denver data and I don't know if we have a dry microburst there. So, we have a partial answer to your question. One of the things that we do see is a unique signature for a microburst. That's really where the differentiation comes between a gust front or a sea breeze or whatever, is in the unique signature of the microburst.

Q: ROB ROSEN (Hughes Aircraft Co.) - How far did the IR sensor see? Was the IR sensor scanning? Was the IR sensor able to estimate range and how accurately? Was it able to estimate the size and the slope of wind shear?

A: DAVE HINTON (NASA Langley) - The sensor was looking about 40 seconds ahead, which is approximately 2 nautical miles at 190 knots. Was the infrared scanning was the next part of the question. The answer to that is no, it's a fixed look point sensor. It's

actually looking at two elevations for various reasons but it's not a scanning in azimuth type situation. The third part, was the infrared sensor able to estimate range and how accurately? The answer to that is that the infrared sensor is not a ranging type instrument and it's not a range gaited instrument. It looks at two points, one very close to the airplane, the near temperature, and it looks at a second point relatively far, called the far temperature. It uses the difference in temperature and the rate of change of that difference to estimate an F-factor. You can call it pseudo ranging if you like because it varies with atmospheric humidity and rain. Pat would you like to add something to that?

PAT ADAMSON (Turbulence Prediction Systems) - We actually do calculate a look distance but it's probably only good to about 20% at best.

Q: DAVE HINTON (NASA Langley) - And it's not presented to the pilot?

A: PAT ADAMSON (Turbulence Prediction Systems) - Not at this time, it could be though but we don't give it out at this time.

A: DAVE HINTON (NASA Langley) - The fourth part of the question, "was it able to estimate the size and the slope of the wind shear?" The output of the infrared sensor is an F-factor estimate based on the scaling laws that have been derived using meteorological models such as Fred Proctor's and real world observations. Again, not being a ranging system it cannot estimate the physical extent of the microburst. It cannot tell you that it's a 1 or 2 or 3 kilometer diameter event. It can only tell you it's there, it's going to be approximately, depending on humidity, 30, 40 seconds in front of the airplane and give you an estimate of the F-factor based on the temperature change and the rate of change of that temperature.

Q: UNKNOWN - You mentioned that it gives us a 20 second warning, was there rain between the aircraft and all the way to 20 seconds in front of the aircraft?

A: DAVE HINTON (NASA Langley) - We're talking about 40 seconds here, not 20. No, the air was relatively dry and we had a very dense rain shaft. Pat Adamson has a video tape that I understand he's going to try and show Thursday which shows it very clearly. There was very good visibility, a good VFR flying day and a very well defined rain shaft associated with the microburst.

Q: SCOTT GRIFFITH (Allied Pilots Association/American Airlines) - Based on your event analysis, how well does the Turbulence Prediction Systems' predictive algorithm work as a reactive system, i.e., does the insitu measurement of delta T correlate well with the wind shear measurement?

A: DAVE HINTON (NASA Langley) - If I understand your question, is it based on a local measurement of F as opposed to a global measurement? People have asked us, "would you expect temperature changes while you're crossing a microburst to correlate to F-factor instantaneously?" We haven't seen the theoretical analysis of the physics that would suggest that's the case. We have always said we expect temperature to correlate extremely well or very well with the total F-factor of the shear but not to necessarily predict the performance increase going in or moment by moment what the F-factor is going to be. However, some of the data we've seen shows that there are correlations. I'm not sure exactly why. You saw in this case there was a performance increase predicted, and a performance decrease predicted. There were even some peaks in the insitu F-factor that could be traced to peaks in the temperature profile as the airplane was flying through and we have seen that in some model cases as well. Pat Adamson has something to add to that.

PAT ADAMSON (Turbulence Prediction Systems) - We've got the data from the infrared sensors and the insitu. The instrument actually receives the outside air temperature from the aircraft plus we have two detectors. For those who will be here on Thursday, I'll be showing that data. The insitu (the calculation of F from the aircraft sensor, the outside air temperature) on the citation calculated a 0.15 F-factor about 15 seconds prior to the insitu from the winds. So we have, if you will, two infrared and one local temperature sensor and with the algorithms we use they all calculated the hazard index within 0.02 of that which was experienced by the winds.

DAVE HINTON (NASA Langley) - To correct something I just said, the infrared detected a performance increasing shear on the far side of the microburst. It did not detect the performance increasing shear prior to getting in there. The reason is, there is no warming to correspond to predicting a negative F-factor. There is warming on the other side as you're exiting.

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